United States Patent
(12) United States Patent
Fukashiro et al.

(10) Patent No.: US 6,987,899 B2
(45) Date of Patent: Jan. 17, 2006

US006987899B2

(54) **OPTICAL SWITCHING APPARATUS AND OPTICAL SWITCHING METHOD**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 15 days.

(21) Appl. No.: **10/728,134**

(22) Filed: **Dec. 4, 2003**

(65) **Prior Publication Data**

US 2004/0120714 A1 Jun. 24, 2004

Related U.S. Application Data

(63) Continuation of application No. 09/946,577, filed on Sep. 5, 2001, now Pat. No. 6,714,697.

(30) **Foreign Application Priority Data**

Jun. 19, 2001 (JP) 2001-184230

(51) **Int. Cl.**
G02B 6/26 (2006.01)
H04B 10/00 (2006.01)

(52) **U.S. Cl.** **385/16**; 385/15; 385/17; 385/24; 398/112; 398/111; 398/113; 398/43; 398/48

(58) **Field of Classification Search** 385/15, 385/16, 17, 18, 24; 398/112, 111, 113, 43, 398/48

See application file for complete search history.

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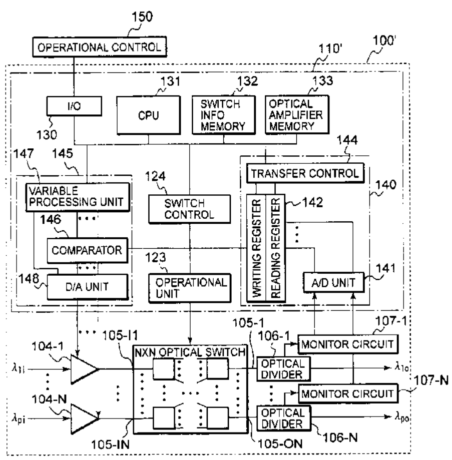
(74) *Attorney, Agent, or Firm*—Knoble Yoshida & Dunleavy LLC

(57) **ABSTRACT**

An optical switching apparatus includes an optical switch having a plurality of input ports and output ports, optical amplifiers, monitor circuits, optical amplifiers monitor circuits, and a controller that controls the optical switch. The optical amplifiers are connected to the input ports of the optical switch. The monitor circuits are connected to the output ports of the optical switch. The controller selects one of the plurality of the monitor circuits based on predetermined rules to obtains the loss at the output ports and/or the differential loss between the channels of the optical switch. The controller further selects one of the optical amplifiers based on the configuration of the optical switch to compensate the loss and the differential loss among the different channels of the optical switch by pre-amplifying the optical signals before they reach the input ports of the optical switch.

4 Claims, 6 Drawing Sheets



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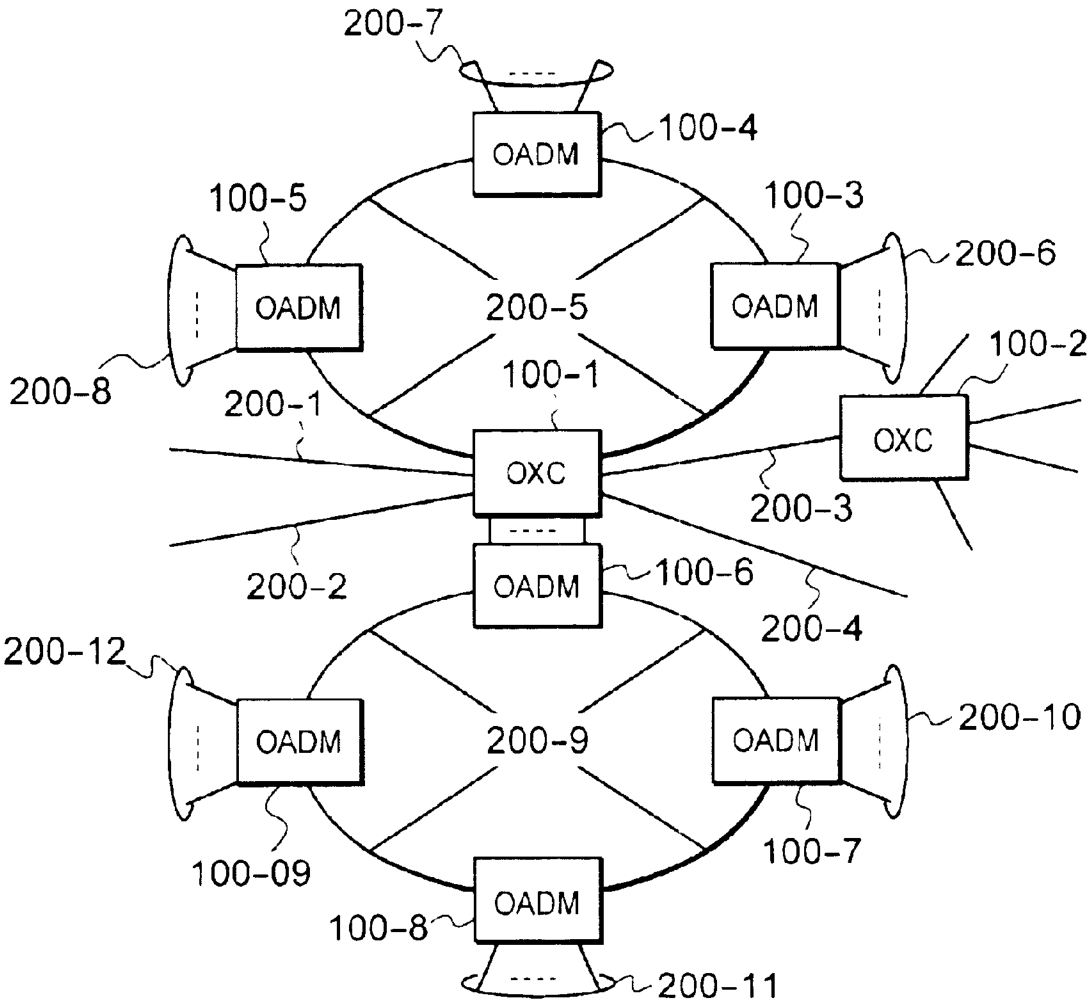
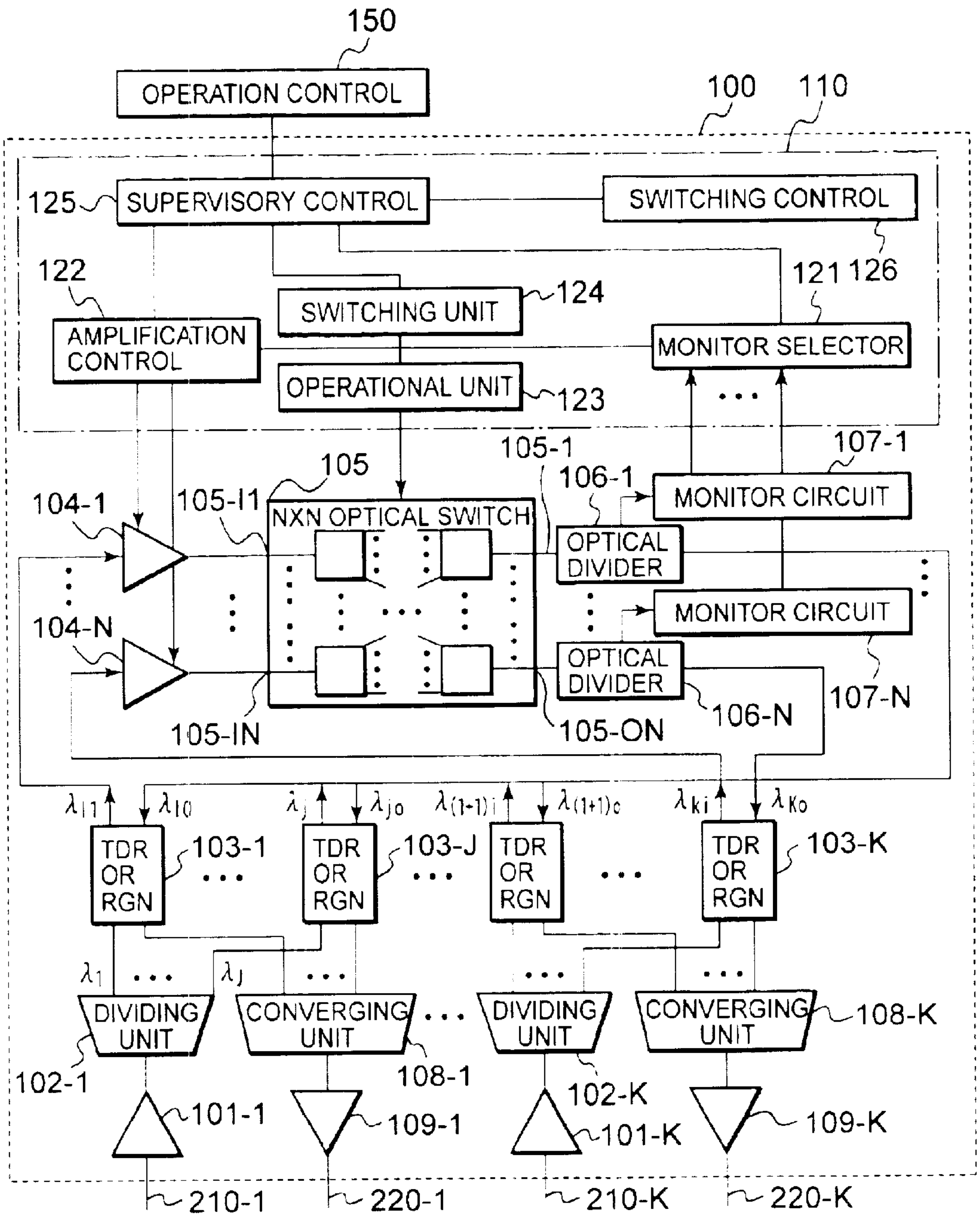

200-7
100-4
OADM
100-5
100-3
200-6
OADM
200-5
OADM
100-2
200-8
100-1
200-1
OXC
OXC
200-3
200-2
OADM
100-6
200-4
200-12
200-9
OADM
OADM
200-10
100-09
100-7
OADM
100-8
200-11

FIG. 1



OPTICAL TRANSMISSION PATH 1 • • • OPTICAL TRANSMISSION PATH K

FIG. 2

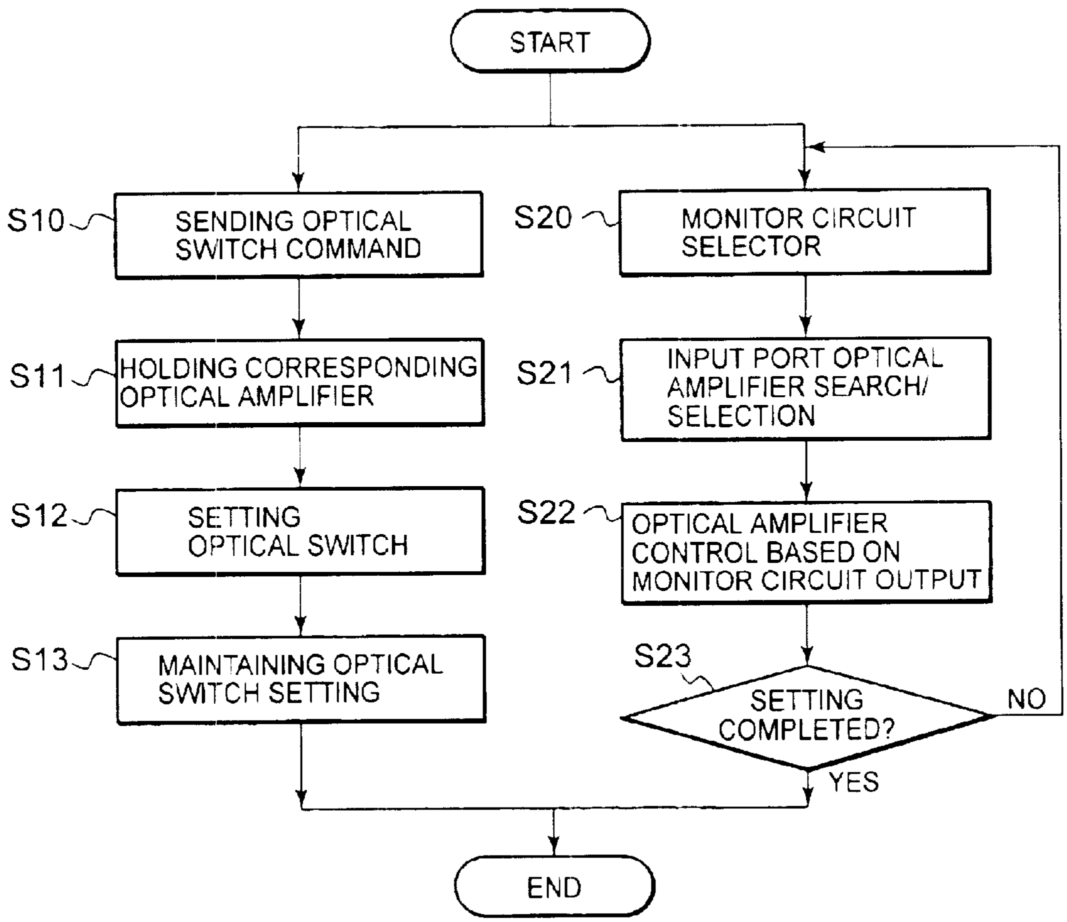
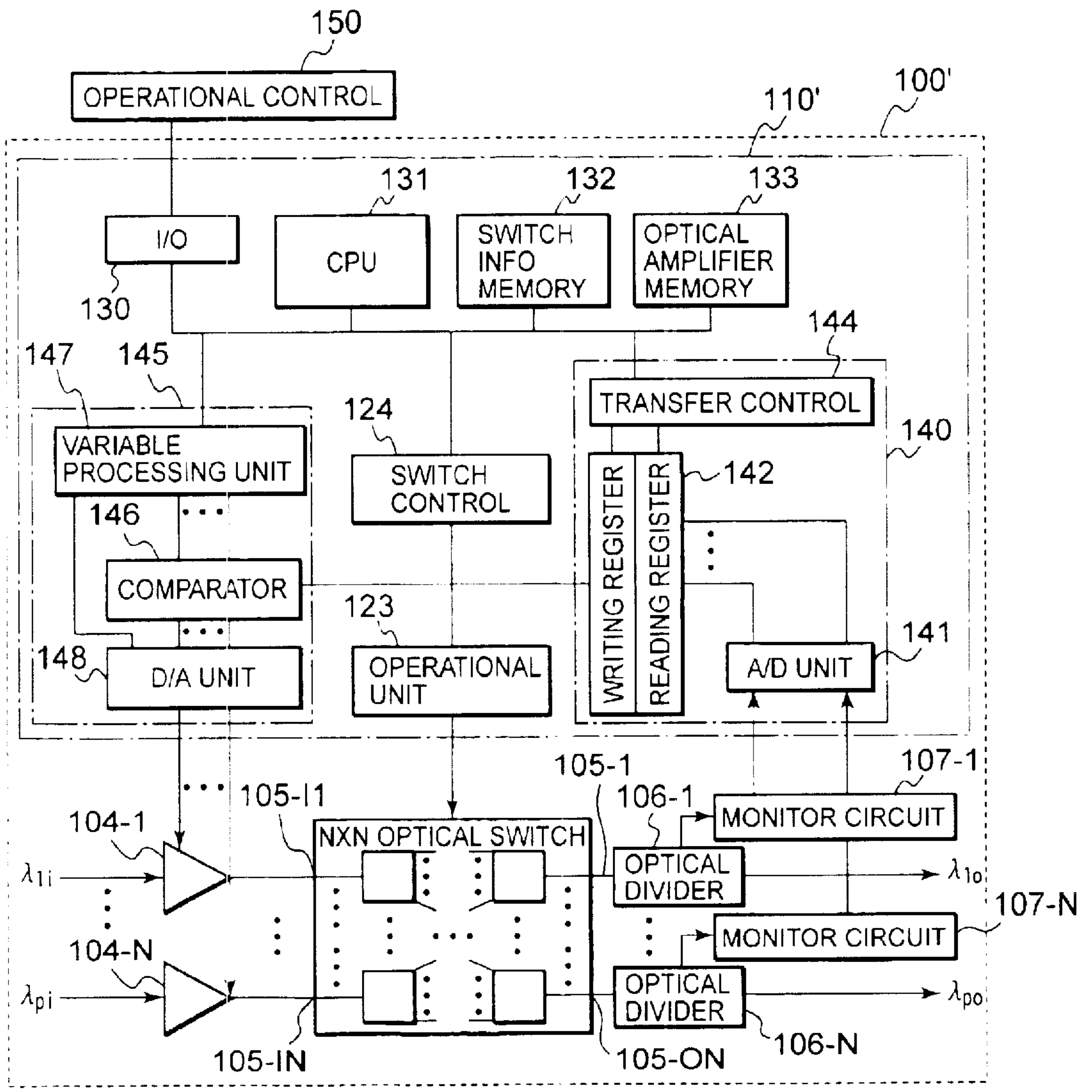

START
S10
SENDING OPTICAL SWITCH COMMAND
S11
HOLDING CORRESPONDING OPTICAL AMPLIFIER
S12
SETTING OPTICAL SWITCH
S13
MAINTAINING OPTICAL SWITCH SETTING
S20
MONITOR CIRCUIT SELECTOR
S21
INPUT PORT OPTICAL AMPLIFIER SEARCH/ SELECTION
S22
OPTICAL AMPLIFIER CONTROL BASED ON MONITOR CIRCUIT OUTPUT
S23
SETTING COMPLETED?
NO
YES
END

FIG. 3



150
OPERATIONAL CONTROL
110'
100'
131
132
133
I/O
CPU
SWITCH INFO MEMORY
OPTICAL AMPLIFIER MEMORY
130
144
147
145
TRANSFER CONTROL
124
140
VARIABLE PROCESSING UNIT
SWITCH CONTROL
142
146
WRITING REGISTER
READING REGISTER
COMPARATOR
123
141
148
D/A UNIT
OPERATIONAL UNIT
A/D UNIT
105-1
107-1
105-I1
106-1
MONITOR CIRCUIT
104-1
NXN OPTICAL SWITCH
λ_{1i}
OPTICAL DIVIDER
λ_{1o}
107-N
104-N
MONITOR CIRCUIT
λ_{pi}
OPTICAL DIVIDER
λ_{po}
106-N
105-IN
105-ON

FIG. 4

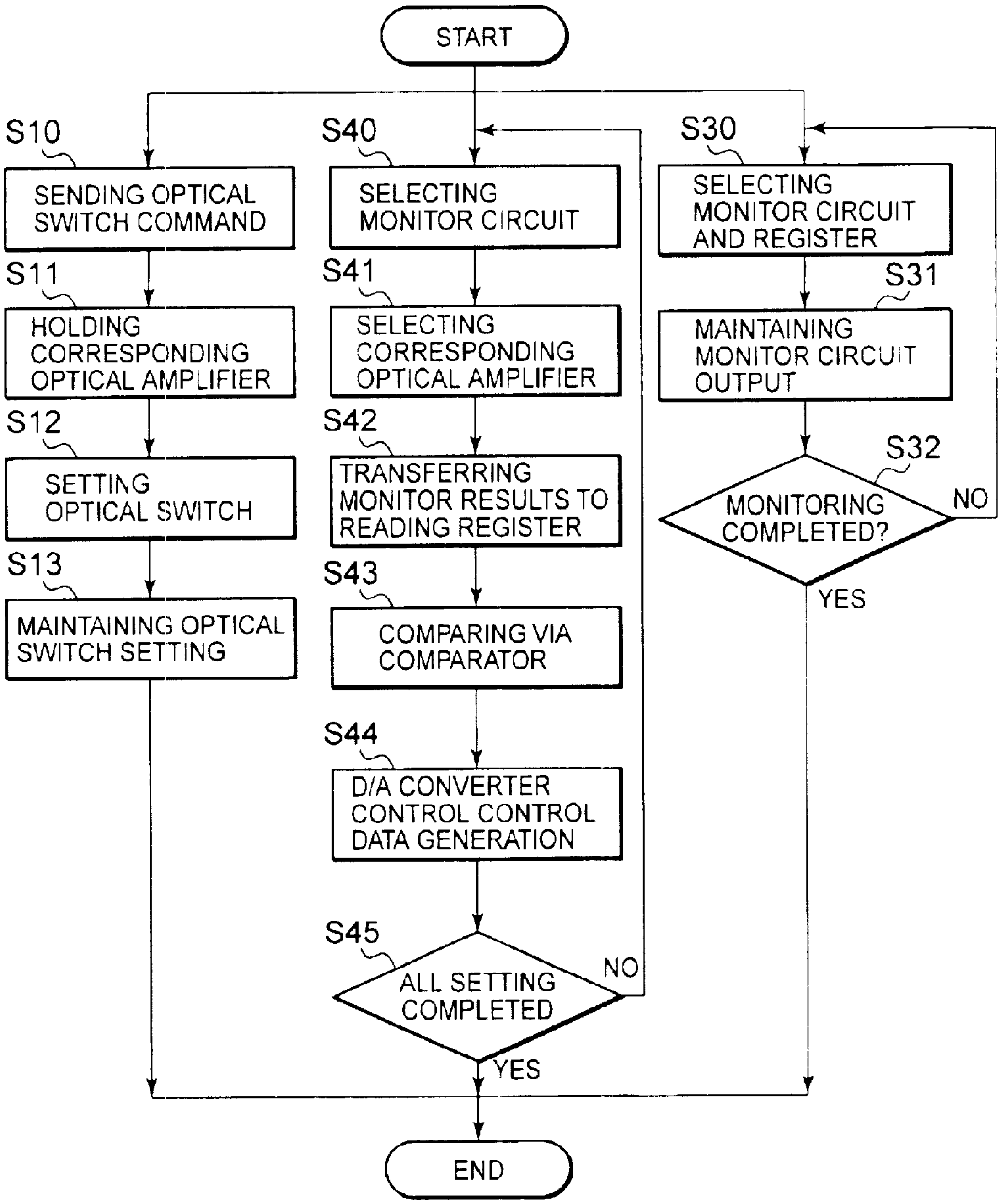

START
S10
SENDING OPTICAL SWITCH COMMAND
S11
HOLDING CORRESPONDING OPTICAL AMPLIFIER
S12
SETTING OPTICAL SWITCH
S13
MAINTAINING OPTICAL SWITCH SETTING
S40
SELECTING MONITOR CIRCUIT
S41
SELECTING CORRESPONDING OPTICAL AMPLIFIER
S42
TRANSFERRING MONITOR RESULTS TO READING REGISTER
S43
COMPARING VIA COMPARATOR
S44
D/A CONVERTER CONTROL CONTROL DATA GENERATION
S45
ALL SETTING COMPLETED
NO
YES
S30
SELECTING MONITOR CIRCUIT AND REGISTER
S31
MAINTAINING MONITOR CIRCUIT OUTPUT
S32
MONITORING COMPLETED?
NO
YES
END

FIG. 5

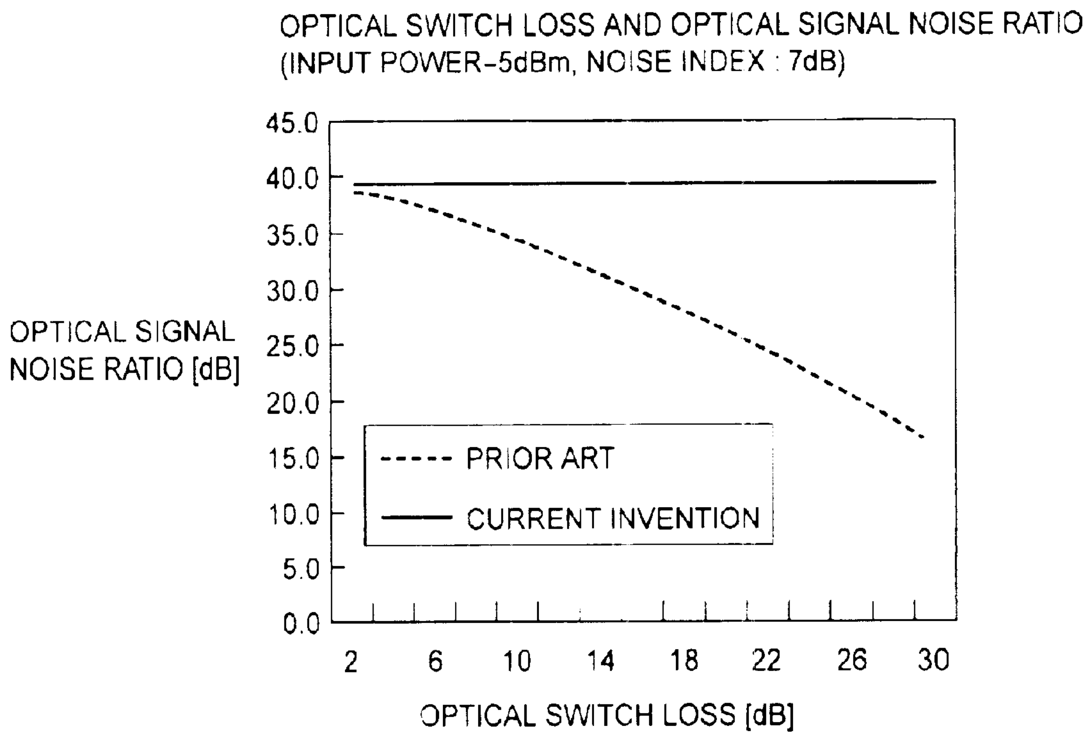

OPTICAL SWITCH LOSS AND OPTICAL SIGNAL NOISE RATIO
(INPUT POWER-5dBm, NOISE INDEX : 7dB)
OPTICAL SIGNAL NOISE RATIO [dB]
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
PRIOR ART
CURRENT INVENTION
2
6
10
14
18
22
26
30
OPTICAL SWITCH LOSS [dB]

FIG. 6

OPTICAL SWITCHING APPARATUS AND OPTICAL SWITCHING METHOD

This is a continuation of prior application Ser. No.: 09/946,577 filed on Sep. 5, 2001, now U.S. Pat. No. 6,714, 697 under 35 CFR 1.53(b),

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an optical communication device and methods of using this device. In particular, the present invention relates to an optical switching apparatus suitable for switching and outputting optical signals received from a plurality of optical transmission lines to other optical transmission lines, and methods for using this apparatus.

2. Prior Art of the Invention

To handle the sudden increase in data traffic through the Internet, etc. and the quickly growing demands for multimedia communication of images, sound and data, much progress has been made to increase the speed and the capacity of the transmission lines and telecommunication network nodes. To achieve a higher transmission speed, optical communication devices and optical fiber transmission lines are generally used to transmit signals between telecommunication network nodes.

In recent years, to handle the ever increasing speed of communication networks and to improve the capacity of communication devices, these communication networks and devices, use optical switching apparatuses such as optical cross-connects (hereafter, referred to as OXC) and optical add-drop multiplexing apparatuses (hereafter, referred to as OADM), which implement switching processes such as switching of transmission lines and switching of circuits without converting optical signals to electric signals before processing the signals as in the conventional communication devices.

The OXC or OADM typically includes optical switches as its main components. At present, since a single stage high-capacity optical switch is not commercially available, a high-capacity optical switch is usually implemented through a multi-stage combination of the commercially available low-capacity optical switches such as 2×2 or 8×8 switches. The optical signal power loss and differential loss among the channels of a commercial low-capacity optical switch might reach from several dB to more than ten dB. These losses between the channels night-be even larger for a high-capacity switch including a multi-stage combination of the commercially available low-capacity optical switches. Typically, an optical communication system includes optical transmitters and optical receivers before and after optical switches. Since these optical transmitters and receivers have limited optical transmission output powers, sensitivities and dynamic ranges, compensation is generally required for the optical switch loss and differential loss between the channels.

Several methods have been proposed to solve this problem. In "A Frequency Multiplexed Routing and Selecting Hybrid Switch," Denshi Joho Tsushin Gakkai [Electronic Information and Communication Association]/Tsushin Society Taikai [Communication Society Conference (1999)]/B-12-17 (Reference A), a method is disclosed to compensate for the losses by placing optical amplifiers in the middle and/or at the output of the multi-stage optical switches. In "Power Control in ADM Node Using High-speed Compact-size Optical Spectrum Monitor," Denshi Joho Tsushin Gakkai [Electronic Information and Communication Association]/Tsushin Society Taikai [Communication Society Conference (1997)]/B-10-101 (Reference B), it is disclosed that a wavelength-division-multiplexed (WDM) optical signal is first wavelength-demultiplexed by an OADM into an optical signal with multiple wavelengths, and that after controlling the optical amplitude for each of the wavelengths using variable optical attenuators, the signals are again wavelength-division-multiplexed. In this method, the amplitude for each wavelength is controlled based on the results of multiplex signal spectrum monitors after wavelength-division-multiplexing.

Kokai Patent Journal No. HEI 11 [1999]-32010 (Reference C) to the inventor of the present application discloses an OXC containing several optical switches and a few optical amplifiers between the optical switches, wherein the optical signal amplitude is controlled using a configuration wherein the amplification of optical signals is adjusted with the optical amplifiers, which is in turn controlled by the amplitude of the output optical signals.

At present, a high-capacity optical switch is usually realized by combining commercially available low-capacity optical switches in multi-stages. Therefore, it is necessary to appropriately calibrate and install an optical transmission line from the output port of an optical switch at one stage to the input port of another optical switch at the next stage. Thus, maintenance is often required for those transmission lines between the stages, and the optical transmission is interrupted during the maintenance. Further, the interruption may also occur when the high-capacity optical switch is under the normal operation.

A high-capacity switching apparatus, in which optical amplifiers are placed inside or after optical switches, such as the ones disclosed in References A and C, often causes sensitivity degradation of the optical parts on the reception side due to light surges caused by the above described interruption of light. Thus, the configuration disclosed in Reference A or C requires a surge-preventing function in the switching controlling unit of the optical switches and/or the controlling unit of the optical amplifiers. Otherwise, the disclosed high capacity switching apparatus needs to use high performance optical parts such as ones with a wide dynamic range. In addition, to compensate for the optical signals which suffer the power loss in the optical switches, the high-capacity switching apparatus includes optical amplifiers placed after the optical switches. Since the spontaneous emission noise of the optical amplifiers is added to the optical signals with a lowered power, the signal-to-noise ratio of the optical signal may decrease and cause errors in the receiver.

Furthermore, the optical signal received by the input port of an optical switch may take various inner paths before reaching the output port, and the optical switch in each stage is appropriately selected and configured. That is, because the characteristics such as the amplitude loss or the differential loss between the channels of each of the switches in the multi-stage combination is different, the loss between the channels of the optical switches between the input port and the output port will significantly vary depending on the actual configuration of optical switches in the multi-stage combination. Therefore, to offer a high performance large-capacity optical switch, it is desirable to realize compensation for the optical switch loss and the differential loss between channels that have occurred in the chosen optical path for each input/output port. The optical switching apparatuses as disclosed in Reference A or C, however, do not offer the above desired function.

Meanwhile, the OADM as disclosed in Reference B adopts a configuration wherein the spectra of wavelength-division-multiplexed optical signals are monitored and the loss is compensated for each demultiplexed wavelength in the OADM. In this configuration, since the wavelength of each signal to be compensated must be different from one another, the wavelengths and the multiplexing methods of the optical signals used as optical switching apparatuses will be limited. In addition, it is still not compatible with either an optical switch with a flexible configuration wherein the wavelengths monitored by the monitor units correspond to the wavelengths processed by the loss compensation units in a one-to-one fashion. It is desired various connections should be adopted with switching. Alternatively, an optical switch should have a flexible configuration with no restrictions in the wavelength of the optical signals in the multiplexing methods.

SUMMARY OF THE INVENTION

In order to solve the above and other problems, according to a first aspect of the current invention, an optical switching apparatus that receives optical signals from a plurality of input circuits and outputs the optical signals to an arbitrary one of a plurality of output circuits, including an optical signal adjusting unit for adjusting the optical signals after being received at the plurality of the input circuits to generate an adjusted optical signal, an optical signal switching unit connected to the optical signal adjusting unit for switching the adjusted optical signal to one of a first output port and a second output port, a first optical signal monitoring unit connected to the optical signal switching unit for monitoring the optical signal sent to the first output port, a second optical signal monitoring unit connected to the optical signal switching unit for monitoring the optical signal sent to the second output port, and a controlling unit connected to the optical signal adjusting unit, the optical signal switching unit and the first and second output signal monitoring units for controlling the optical signal adjusting unit based upon an output signal, the output signal being sent from the first optical signal monitoring unit if the optical signal is sent to the first output port, the output signal being sent from the second optical signal monitoring unit if the optical signal is sent to the second output port.

According to the second aspect of the current invention, an optical switching apparatus that receives optical signals from a plurality of input circuits and outputs an arbitrary one of the optical signals to an output circuit, including a first optical signal adjusting unit for adjusting an optical signal from a first input circuit to generate a first adjusted optical signal, a second optical signal adjusting unit for adjusting an optical signal from a second input circuit to generate a second adjusted optical signal, an optical signal switching unit connected to the first optical signal adjusting unit and the second optical signal adjusting unit for outputting one of the first adjusted optical signal and the second adjusted optical signal, an optical signal monitoring unit connected to the optical signal switching unit for monitoring the optical signal from the optical signal switching unit, and a controlling unit connected to the first optical signal adjusting unit, the second optical signal adjusting unit, the optical signal switching unit and the optical signal monitoring unit for controlling the first optical signal adjusting unit and the second optical signal adjusting unit based upon the output signal from the optical signal monitoring unit, if the first adjusted optical signal is outputted, the controlling unit controlling the first optical signal adjusting unit based upon the output signal, if the second adjusted optical signal is outputted, the controlling unit controlling the second optical signal adjusting unit based upon the output signal.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the present invention will now be described in conjunction with the accompanying drawings, in which;

FIG. **1** is a schematic diagram illustrating an example of configuration of a communication network equipped with one preferred embodiment of the optical switching apparatus according to the present invention;

FIG. **2** is a schematic block diagram, which illustrates an example of configuration of an optical switching apparatus of the present invention;

FIG. **3** is an operational flow chart, which illustrates an example of operation of the controller;

FIG. **4** is a schematic block diagram, which illustrates another example of configuration of an optical switching apparatus of the present invention;

FIG. **5** is an operational flow chart, which illustrates another example of operation of the controller;

FIG. **6** is an explanatory diagram, which illustrates an example of improvement of optical signals by means of an optical switching apparatus of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The optical switching apparatus of the present invention and methods for using this apparatus will be described in detail using the drawings.

FIG. **1** is a schematic diagram of a network, which illustrates an example of configuration of a communication network wherein the optical switching apparatuses of the present invention are used. The optical switching apparatuses or the OADM'S **100-1~100-9** are interconnected with optical fibers **200-1~200-12** to form a communication network. Specific types of the optical switching apparatuses include optical cross-connects or OXC, **100-1**, **100-2**, which switch, multiplex and output the multiplexed optical signals received from each of the input optical fibers, **200-1~200-5** to the output optical fibers. Other switching apparatuses include the optical add-drop multiplexing apparatuses, OADM **100-3~100-9**, which separate or insert the optical signals needed for the OADMs connected to the other OADMs from the multiplexed optical signals received from the optical fibers **200-5** and **200-9**. The OADM'S **100-3~100-9** transmit the optical signals through the optical fibers **200-6~200-12** among the OADMs. The communication network is formed by connecting these optical switching apparatuses of the present invention with the optical fibers that transmit the optical signals having an appropriately multiplexed level and transmission speed that are required of the communication network.

Furthermore, the optical switching apparatuses of the present invention easily build a communication network in a flexible configuration that handles various transmission speeds and levels of multiplexed optical signals by appropriately selecting the components in the optical switching apparatus. For instance, the optical signal has a speed at or above STM-0 (51.84 MHz) as specified by the ITU-T recommendation, or the optical signal is an un-modulated direct current light. In addition, there is no limitation to the presence or absence of wavelength-division-multiplexers or the number of wavelength-division-multiplexers either. For instance, to handle 16 wavelength-division-multiplexers signal counts and 4 switching directions, an OXC with a switching scale of around 64×64 will be needed. In this case, it would be difficult to realize a compact signal switching apparatus with electronic circuits when the transmission speed is 2.5 G bits per second, 10 G bits per second or faster. However, the optical switching apparatus of the present invention easily handles the above tasks.

FIG. **2** is a schematic block diagram, which illustrates an embodiment of the structure of the optical switching apparatus according to the present invention. The optical switching apparatus **100** in this embodiment includes K pieces of optical fibers **210-1~210**-K, and **220-1~220**-K for respectively inputting and outputting optical signals. The optical switching apparatus **100** offers the OXC function. After receiving a plurality of wavelength multiplexed optical signals (for instance, j wavelength) from a particular one of the optical fibers **210-1~210**-K, N×N optical switch **105** switches them toward the destinations of the optical signals. The optical signals are compensated for the loss and the differential loss among the channels due to the particular one of the optical fibers **220-1~220**-K to which the optical signals are switched by N×N optical switch **105**.

Specifically, the optical signals received from the particular one of the optical fibers **210-1~210** -K through a particular one of the optical input circuits **101-1~102**-K that is the realized by means of optical amplifiers, etc. are wavelength-demultiplexed by a particular one of wavelength demultiplexers **102-1~102**-K for each wavelength. The optical signal of each wavelength has its wavelength converted or regenerated by a particular one of the transponders or regenerators **103-1~103**-K (TDR or RGN), which is then fed to a particular one of the optical amplifiers **104-1~104**-N of the optical switching apparatus of the present invention.

After passing through a particular input ports **105-I1~105**-IN of N×N optical switches **105**, the optical signal, with its amplitude being controlled by a particular optical amplifiers **104-1~104**-N depending on the particular input circuit, is switched and transferred to one of the output ports **105**-O1~**105**-ON of the optical switches **105** depending on the destination of the optical signal. The optical signal switched by the optical switches **105** passes through optical splitters or optical couplers **106-1~106**-N. The optical signal of each wavelength is then converted or regenerated by transponders or regenerators **103-1~103**-K (TDR or RGN) in the same manner as the optical signal being converted or regenerated before reaching the particular input ports **105 I1~105**IN of the optical switch **105**. Optical signals with different wavelengths are then appropriately wavelength-division-multiplexed by the wavelength multiplexers **108-1~108**-K, and are then outputted to the optical fibers **220-1~220**-K through the output circuits **109-1~109**-K that are realized by optical amplifiers, etc. in the same manner as the input circuits.

Monitor circuits **107-1~107**-N monitor the state of the optical signals such as the optical signal amplitude and the differential loss between the channels at each output port of the optical switch **105**. A controller **110** includes a monitor selector **121**, for selecting one of the monitor circuits **107-1~107**-N, an amplifier controller **122** that controls each of the optical amplifiers **104-1~104**-N, which compensate optical signals before their reaching the input ports **105I1~105**IN according to the state of the outputted optical signal, an optical switch driver **123**, a switch control unit **124**, which sets up the optical transfer paths from the input ports **105-I1~105**IN to the output port **105**-O1~**105**ON of the optical switch **105** and a supervisory control unit **125**, which supervises and controls the optical switching apparatus **100** by interlocking with the monitor selector **121**, amplifier controller **122**, and switch control unit **124**. Furthermore, the controller **110** further includes a switch management unit **126** for managing and storing the switch configuration information needed to set up the optical switch, the information on the actually set-up paths within the switch, etc. This controller **110** further communicates with the operation management unit **150** regarding the monitoring or controlling of the optical switching apparatus **100** of the present invention sets up the optical switch **105**, and compensates for the loss and differential loss among the channels of the optical switch by controlling the monitor circuit **107-1~107**-N and the optical amplifier **104-1~104**-N.

FIG. **3** is an operational flow chart, which describes the operation of the controller **110** of the optical switching apparatus **100** of the present invention. Using FIGS. **2** and **3**, the setup in the optical switching apparatus according to the present invention and the operation for compensating for the loss and the differential loss between the channels of the optical signal will be described in detail.

(1) Setup in Optical Switch

When an optical switch **105** setup or "switching" command is received in step **S10** from the operation management unit **150**, the optical amplifiers **104-1~104**-N related to the applicable input port is put on hold in step **S11**, the path from the input port to the output port of the optical switch **105** is set up or switched in step **S12**. The connection set-up information is held in the switch management unit **126** or equivalence thereof. Furthermore, the purpose of putting the optical amplifiers **104-1~104**-N on hold in step **S11** is to avoid the unstable operation of the optical amplifiers **104-1~104**-N while the monitor circuit **107-1~107**-N are switched. The same effect is also obtained by setting the response speed of the optical amplifiers **104-1~104**-N at a slower speed than the switching speed of the monitor circuit.

(2) Compensation for Optical Signal

When one of the monitor circuits **107-1~107**-N is selected in step **S20** according to the predetermined rules (cycles, supervisory orders, etc.), the supervisory control unit **125** searches and selects one of the optical amplifiers **104-1~104**-N connected to the input port corresponding to the output port that corresponds to this selected monitor circuits **107-1~107**-N from the pre-held connection set-up information in step **S21**.

The feedback from the selected one of the monitor circuits **107-1~107**-N is inputted from the monitor selector **121** to the amplifier controller **122**. The amplifier controller **122** controls the selected one of the optical amplifiers **104-1~104**-N by assigning the received feedback from the monitor circuit to the selected one of the optical amplifiers **104-1~104**-N during the selection step **S21** using internal switches (not illustrated) in the amplifier controller **122** thereby to compensate for the loss and the differential loss between the channels of the optical signal at the optical switch output ports.

This compensation operation comprising the steps **S20**, **S21** and **S22** is repeated until all the proper optical paths are set up in the optical switch **105**. Step **S23** checks if all the optical paths have been set up.

The optical switch **105** used in the optical switching apparatus **100** of the present invention is preferably an N×N high-capacity switch, which may be produced by combining multi-stage commercially available low capacity switches such as 2×2, 8×8, 16×16 switches. For instance, the SiO2 waveguide-based optical switch is disclosed in the OFC 2000 (Optical Fiber Communication Conference) TuM2-1/207 (March 2000, p. p. 207); the MEMS (Micro Electro Mechanical Systems) optical switch is disclosed in the OECC '98 (Third Opt electronics and Communications

Conference) 15D1-8 (July 1998, p. p. 400), the inkjet bubble technology-based optical switch is disclosed in the OFC 2000 TuM1-1/204 (March 2000, p. p. 204); and the mechanical optical switch is disclosed in the 1997 Denshi Joho Tsushin Gakkai [Electronic Information and Communication Association/Tsushin [Communication] Society Conference/B-10-189. The above switches are appropriately used as the low-capacity switch to form the N×N high-capacity switch used in the optical switching apparatus according to the present invention. Of course, if a single stage high-capacity optical switch becomes commercially available in the future, such a single stage high-capacity optical switch may be used as the optical switch **105** used in the present invention.

Furthermore, the optical switching apparatus **100** of the present invention does not require special components for the optical amplifiers **104-1~104**-N, and optical splitters or optical couplers **106-1~106**-N. Commercialized standard parts are in the optical amplifiers **104-1~104**-N and optical splitters or optical couplers **106-1~106**-N. Also, depending on the level of loss compensation required for the optical switch **105** or the performance of its peripheral equipments, devices such as variable optical attenuators, that control the characteristics of optical signals, are optionally used in place of the optical amplifiers **104-1~104**-N.

Through its optical amplifiers **104-1~104**-N, the optical switching apparatus **100** of the present invention properly compensates the loss and differential loss in optical signals after they pass through different channels in the optical switch **105** by monitoring the output ports of the optical switch **105**, in a high capacity optical switch. In addition, the compensation to the loss and differential loss of the optical signals is made while the controller is in the process of selecting the monitor circuit. Furthermore, an optical switching apparatus containing a high capacity optical switch properly compensates for the loss and the differential loss between the channels of the optical signal even while it is in service. The optical switching apparatus of the present invention requires only a simple configuration and procedure.

More preferably, the optical switch apparatus **100** of the present invention further optionally includes receiving circuits **101-1~101**-K, wavelength demultiplexers **102-1~102**-K, transponders or regenerators **103-1~103**-K, wavelength multiplexers **108-1~108**-K and transmitting circuits **109-1~109**-K depending on the condition such as the speed or the level of multiplexing of optical reception, which is transmitted and received through optical fiber, under which the optical switching apparatus **100** of the present invention is used. In an alternative embodiment of the optical switching apparatus of the present invention, the optical fibers **210-1~210**-K, **220-1~220**-K are directly connected to the optical amplifiers **104-1~104**-N and the optical splitters or optical couplers **106-1 ~106**-N.

The aforementioned configuration in FIG. **2** is an embodiment of an OXC, which is one type of the optical switching apparatus according to the present invention. In an OADM, which is another type of the optical switch apparatus, a partially separated or inserted optical signal in the OADM, is directly inputted from the optical amplifiers **104-1~104**-N and outputted to the optical splitters or optical couplers **106-1~106**-N, or is inputted to and outputted from the TDRs or the RGNs **103-1~103**-K.

Since the loss compensation for the optical switch **105** is respectively made by the optical amplifiers and the monitor circuits on the input and output sides of the optical switch, the loss compensation is not influenced by the peripheral optical fibers or the optical signals. Therefore, the optical switching apparatus of the present invention has few restrictions on the wavelengths of the optical signals and the multiplexing methods.

FIG. **4** illustrates another embodiment of an optical switching apparatus of the present invention. In the optical switching apparatus **100'** of FIG. **4**, the input circuits and output circuits of the OXC illustrated in FIG. **2** are simplified, and the configuration of the controller **110** is replaced by another controller **110'**, which implements the control with firmware or software. Hereafter, the configuration of the controller **110'**, which is different from the controller **110** in FIG. **2**, and the operation of controller **110'** will be explained. In FIG. **4**, the components that are substantially identical to those in FIG. **2** are labeled with the same number.

The controller **110'** includes an IO unit **130** and an operation management unit **150**. The IO unit **130** is connected to and communicates with the operation management unit **150**. The controller **110'** further includes a CPU **131** which controls the controller **110'**, a monitor selector **140**, an amplifier controller **145**, and a switch control unit **124** for an optical switch **105** through a bus **136**. Switch information memory **132**, which is an internal memory, stores the connection set-up information for the optical switch **105**. An optical amplifier memory **133** stores the control target value or the alarm information. Based on a firmware or software stored in a CPU memory (not illustrated), CPU **131** controls each of the aforementioned units. Optionally, the switch information memory **132**, the optical amplifier memory **133** and the CPU memory reside on a single memory chip.

The monitor selector **140** includes analog-to-digital converters **141** that convert a feedback signal from each one of the monitor circuits **107-1~107**-N into digital data. The monitor selector **140** further includes a data storage device including a writing register **142** and a reading register **143** that hold the digital data The monitor selector **140** further includes a transfer control-unit **144** that controls the writing register **142** and the reading register **143**. Optionally, the transfer control unit **144**, the writing register **142** and the reading register **143** reside in the CPU **131** and/or the memory chip(s).

The amplifier controller **145** includes a comparator **146** that compares the digital data, which is the feedback from each one of the monitor circuit **107-1~107**-N with control target values in the optical amplifier memory **133**. A parameter-processing unit **147** selects a particular one of the optical amplifiers **104-1~104**-N to be controlled based on the above comparison result and generates control data. A digital-to-analog converter **148** converts the control into analog signals to control the particular one of the optical amplifiers **104-1~104**-N. Optionally, the comparator **146**, the optical amplifier memory **133** and the parameter-processing unit **147** reside in the CPU **131** and/or the memory chip(s). Optionally, CPU **131** performs all of the processing steps of the amplifier controller **145** except for the-step of the A/D conversion.

FIG. **5** is an operational flow chart that describes the operation of the controller **110'** in the apparatus of FIG. **4**.

The controller (**110'**) in the aforementioned configuration operates as follows to compensate for optical signals. (1) Set-up of optical switch: Same as the steps **S10** through **S13** in FIG. **3**. Holding the connection set-up information in the switch information memory **132** in the Step **S13**.

(2) Compensation for Optical Signal

a) The CPU **131** notifies the transfer control unit **144** for the particular one of the monitor circuits **107-1~107**-N to be monitored and select a particular area of the write register **142** to store the feedback signal from the monitor circuits **107-1~107**-N in Step S**30**. The transfer control unit **144** stores the digital data, that is the feedback signal from the selected one of the monitor circuits **107-1~107**-N and has been converted into digital data by the analog-to-digital converter **141** in the particular area of the write register **144** in Step S**31**. The CPU **131** repeats the steps **S30** and **S31** until all the paths have been set up in the optical switch **105** using the predetermined rules such as cycles, supervisory orders, etc. and the connection information stored in the switch information memory **132** Step S**32**.

b) Meanwhile, when one of the monitor circuits **107-1~107**-N is selected in Step **S40** according to the predetermined rules such as cycles, supervisory orders, etc., the CPU **131** searches and selects a particular one of the optical amplifiers **104-1~104**-N that is connected to a particular input port based on the selected monitor circuit and the connection set-up information in the switch information memory **132** in Step **S41**.

Through the transfer control unit **144**, the digital data, that is the feedback signal from the selected monitor circuit is transferred from the write register **142** to the readout register **143**, and finally to the comparator **146** in Step **S42**.

The comparator compares the digital data received in Step **S42** and the control target value obtained from the optical amplifier memory **133** and generates a result in Step **S43**. The parameter-processing unit **147** prepares the parameters based on the comparison result in Step **S43** to control the particularly selected one of the optical amplifiers **104-1~104**-N, and controls the selected one of the optical amplifiers **104-1~104**-N through the digital-to-analog converter **148** in Step **S44** to compensate for the loss and the differential loss among the different channels of the optical signals at the optical switch output port.

The above compensation steps **S40 S44** are repeated until all the optical paths in the optical switch **105** have been set up Step S**45**. Through its optical amplifiers **104-1~104**-N, the optical switching apparatus **100**' of the present invention properly compensates the loss and differential loss in optical signals after they pass through different channels in the optical switch **105** by monitoring the output ports of the optical switch **105**. In addition, a high-speed and high-capacity optical switching apparatus with a simple configuration and the procedure and method of using this apparatus are describe as follows: Since the CPU **131** selects the one of the monitor circuits **107-1~107**-N based on the content of the firmware or the software, the loss and the differential loss among the channels of the optical signals is easily and securely compensated even while the apparatus **100**' is in service. Furthermore, when the optical connection configuration of the apparatus is changed, such a change is easily incorporated by modifying the firmware or the software in the optical switching apparatus **100**'.

FIG. **6** is an explanatory diagram that illustrates an example of the improvement of optical signals made by the optical switching apparatus of the present invention. When the optical switching apparatus **100** or **100**' of the present invention is implemented in a communication network, the actual loss or differential loss among the channels of the optical switch is monitored on the output side of the optical switch. The monitored result is fed back to the optical amplifier at the input side of the optical switch, and the optical switch is operated with the pre-compensated optical signal. Therefore, the loss that actually occurred at the connection set-up or the switching of the optical switch is compensated, and an optical signal-to-noise ratio is kept constant independent of the loss.

According to the optical switching apparatus of the present invention and method for use thereof, even if a high capacity optical switch is used in the optical switching apparatus, the loss and the differential loss among the channels of the optical signal through the optical switch is monitored on the output port side of the optical switch. Therefore, the optical signal is properly compensated with a simple configuration and procedure using the optical amplifier on the input port side of the optical switch based on the monitored feedback signal.

We claim:

1. An optical switching apparatus that receives optical signals from a plurality of input circuits and outputs the optical signals to an arbitrary one of a plurality of output circuits, comprising:

an optical signal adjusting unit for adjusting the optical signals after being received at the plurality of the input circuits to generate an adjusted optical signal;

an optical signal switching unit connected to said optical signal adjusting unit for switching the adjusted optical signal to one of a first output port and a second output port;

a first optical signal monitoring unit connected to said optical signal switching unit for monitoring the optical signal sent to said first output port;

a second optical signal monitoring unit connected to said optical signal switching unit for monitoring the optical signal sent to said second output port; and

a controlling unit connected to said optical signal adjusting unit, said optical signal switching unit and said first and second output signal monitoring units for controlling said optical signal adjusting unit based upon an output signal, the output signal being sent from said first optical signal monitoring unit if the optical signal is sent to the first output port, the output signal being sent from said second optical signal monitoring unit if the optical signal is sent to the second output port.

2. The optical switching apparatus according to claim **1** wherein said controlling unit further comprises a memory unit for storing information for said optical signal switching unit, the information being indicative of sending the optical signal to one of a first output port and a second output port, said controlling unit selecting one of said first optical signal monitoring unit and said second optical signal monitoring unit for controlling said optical signal adjusting unit based upon the information.

3. An optical switching apparatus that receives optical signals from a plurality of input circuits and outputs an arbitrary one of the optical signals to an output circuit, comprising:

a first optical signal adjusting unit for adjusting an optical signal from a first input circuit to generate a first adjusted optical signal;

a second optical signal adjusting unit for adjusting an optical signal from a second input circuit to generate a second adjusted optical signal;

an optical signal switching unit connected to said first optical signal adjusting unit and said second optical signal adjusting unit for outputting one of the first adjusted optical signal and the second adjusted optical signal;

an optical signal monitoring unit connected to said optical signal switching unit for monitoring the optical signal from said optical signal switching unit; and

a controlling unit connected to said first optical signal adjusting unit, said second optical signal adjusting unit, said optical signal switching unit and said optical signal monitoring unit for controlling said first optical signal adjusting unit and said second optical signal adjusting unit based upon the output signal from said optical signal monitoring unit, if the first adjusted optical signal is outputted, said controlling unit controlling said first optical signal adjusting unit based upon the output signal, if the second adjusted optical signal is outputted, said controlling unit controlling said second optical signal adjusting unit based upon the output signal.

4. An optical switching apparatus according to claim **3** wherein said controlling unit further comprises a memory unit for storing information for controlling said optical signal switching unit, the information being indicative of outputting one of the first adjusted optical signal and the second adjusted optical signal, said controlling unit selecting one of said first optical signal adjusting unit and said second optical signal adjusting unit based upon the information.

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